PERFORMANCE OF THE RHIC IPM

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Abstract

Four ionization beam profile monitors (IPM's) are in RHIC to measure vertical and horizontal profiles in the two rings. Each IPM collects and measures the distribution of electrons in the beamline resulting from residual gas ionization during bunch passage. The IPM's performed well during the 1999 commissioning run and early in the 2000 run. However as the bunch intensity increased there was a beam-induced ringing that increased in amplitude until it saturated the amplifiers and made the IPM's unusable. Near the end of the run the cause of the ringing was found and one IPM was fixed. At the start of the 2001 run all four IPM have EMI shielding installed.

1. INTRODUCTION

The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Lab [1] has four ionization profile monitors (IPM's) [2,3] for measuring the horizontal and vertical beam profiles in each of the two rings. An IPM measures the transverse beam profile by collecting and measuring the distribution of electrons generated by ionization of residual gas in the beamline. Similar detectors are used at Fermi National Lab [4], DESY [5], and CERN [6].

During beam commissioning in 1999 one complete IPM system was installed and tested [7]. The bunch intensities were about 10% of the design goal making it necessary to generate a gas pressure bump of 10^{-7} torr in the detector chamber to measure a profile. With the pressure bump we measured a clean profile of a single bunch on every revolution. In addition to the signal from the collected electrons there was a small amount of rf ringing on each channel from beam coupling.

In the 2000 beam run the bunch intensities increased until the beam-induced ringing grew large enough to saturate the amplifiers and make the monitors unusable. One complete IPM system was removed from the tunnel and reassembled on the bench. Using a pulsed-wire measurement the source of the ringing was found to be a resonance in the shielding that was installed to prevent beam-detector coupling.

A partial rebuild of the EMI shielding on one detector lowered the coupling enough that some emittance growth data were taken at the end of the run [8]. New EMI shields were installed on all detectors before the 2001 run and early in the run the blue-ring detectors show good profiles.

2. BEAM-INDUCED RINGING

Figure 1 is a photograph of the original detector head which is described in refs. 2 and 3. An 8x10 cm microchannel plate (MCP) is attached to a collector anode board with 64 channels spaced 0.6mm center-to-center. The anode assembly is mounted on the rectangular brackets at the bottom of the picture. Across from the collector, at the top of the picture, is a sweep-field electrode with a secondary-electron suppression grid. The beam passes between these parallel to the flange.

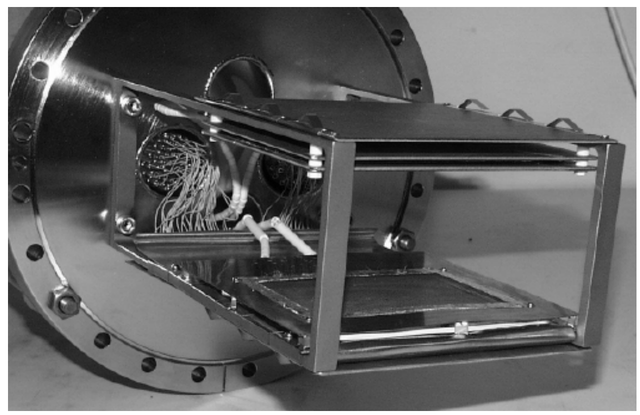

Figure 1: Photograph of original detector head. The copper screen over the MCP is shown at the bottom. Chip capacitors around the EMI screen were responsible for the beam-induced ringing.

When a beam bunch passes through the detector it ionizes some of the background gas. A transverse electric field sweeps the electrons into the MCP which then delivers charge pulses to the anodes. A charge-sensitive amplifier and shaper amplifier connected to each channel delivers a 100-ns long pulse to a digitizer. With the sweep field and MCP bias off there should be no signal with beam.

To decouple the detector from the beam the anode-MCP assembly was wrapped in phosphor bronze sheet. A copper mesh window was placed over the MCP input with bypass capacitors to ground on the corners and sides. Network analyzer measurements made with a taut wire on the axis of the detector chamber showed this screen dropped broadband coupling by >20dB to the noise floor of the measurement.

When installed in the ring however a passing bunch induced ringing with all detector voltages off. This was traced to the rf decoupling screen. The passage of a bunch would charge the upstream and downstream capacitors to opposite polarities and current would oscillate longitudinally along the screen. This was confirmed by sending 20ns pulses along the taut wire with FET scope probes attached to the ends of the screen. The coupling was greatly reduced and the ringing eliminated by replacing the rectangular support brackets with open-ended brackets and fitting a grounded sheath with mesh window over all of the collector wiring.

3. INJECTED BEAM PROFILES

All four detectors were installed for the 2001 RHIC run. At the time of this writing the blue ring has been operating for a week. The data in this section are from the vertical IPM. Figure 2 shows a mountain-range plot of a single bunch for 50 turns at injection. Betatron oscillations are clearly visible. One profile from the data in fig. 2 is shown in fig. 3. The markers are the measured points and the curve is a gaussian fit. The fitted curve has a width of σ=5.9±0.2mm.

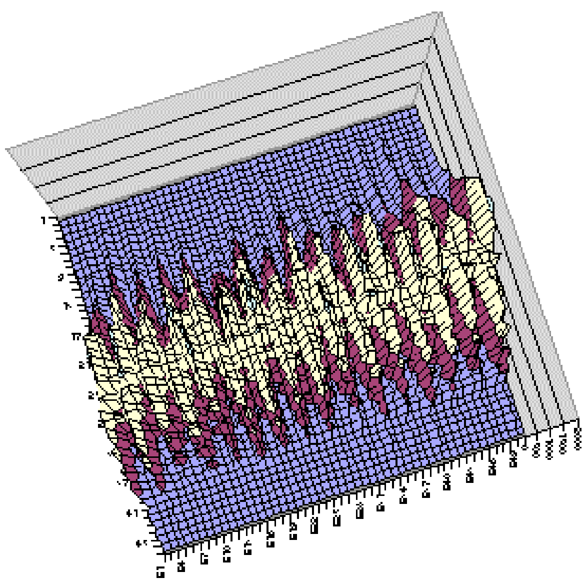

Figure 2: Mountain-range plot of the profile of a single bunch for 50 turns at injection. The detector channels are plotted on the vertical axis and the turns are on the horizontal axis.

Several bunches were injected and for each one a set of 200 turns was recorded. From each of these data sets a series of 128 profiles was analyzed for frequency components. First the centroid of each profile was found. This sequence of beam positions was Fourier transformed to produce the power spectrum shown in fig. 4. The fractional tunes measured with the tune meter were 0.135 horizontal and 0.320 vertical which agree with the IPM data.

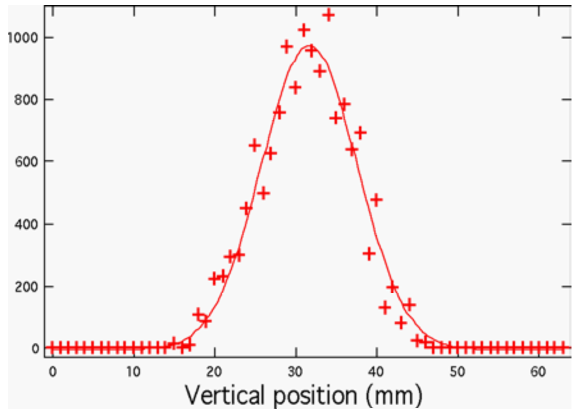

Figure 3: One profile from the mountain-range plot of fig. 2. This is a measurement of a single bunch passing once through the IPM.

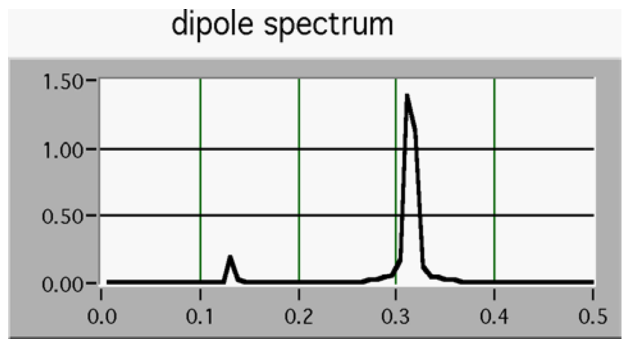

Figure 4: The power spectrum of the beam centroids on 128 consecutive turns. The line at 0.13 is the horizontal tune and 0.32 is the vertical tune.

For each measured profile the rms width about the calculated centroid was calculated. The series of 128 profile widths was Fourier transformed to produce the quadrupole spectrum shown in fig. 5. Since the sampling is done at the revolution frequency the Nyquist frequency is at 0.5. The vertical quadrupole oscillation at 0.64 is aliased to 0.36.

4. STORED BEAM GROWTH

A single bunch was stored for about 45 minutes. During this time both horizontal and vertical IPM's measured profiles at 4 second intervals. The results of this measurement are shown in fig. 6. Each plotted width is the result of averaging 200 turns. The top trace plots the vertical widths and the center trace plots the horizontal widths. The bottom traces are the vertical and horizontal profile heights. There is gain feedback in the software which adjusts the MCP bias to keep the profiles at a constant height to prevent amplifier saturation.

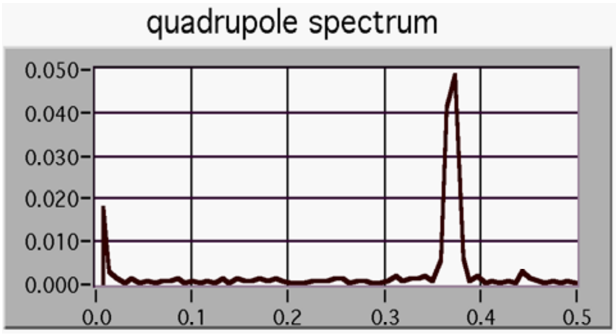

Figure 5: Power spectrum of the bunch widths on 128 turns. The quadrupole line at 0.64 is above Nyquist so it is aliased to 0.36.

At 05:40 on the time axis the old bunch was dumped and a new one injected. The new bunch came in with a clean horizontal profile but the vertical profile had a distorted shape which is probably related to the width variation. The new bunch came into the machine with approximately the same emittance as the previous bunch had started with. During the store several people were working on the machine so this is not a measurement of machine performance but is intended to show the capability of the IPM.

5. CONCLUSION

The beam-induced ringing discovered in the 2000 run has been eliminated. There is still some beam coupling which may cause problems as the bunch intensity is increased. The problem of providing a window to electrons with no electromagnetic coupling is still being worked on. Early results show that the IPM can be used both for emittance measurements and for optical matching.

ACKNOWLEDGEMENTS

Since the last run two IPM's had to be moved. This was a big project and was handled superbly by Robert Sikora, Phil Cerniglia, and John Cupolo. Al Della Penna and Robert Bennett did most of the detector rebuild. This work was performed under the auspices of the United States Department of Energy.

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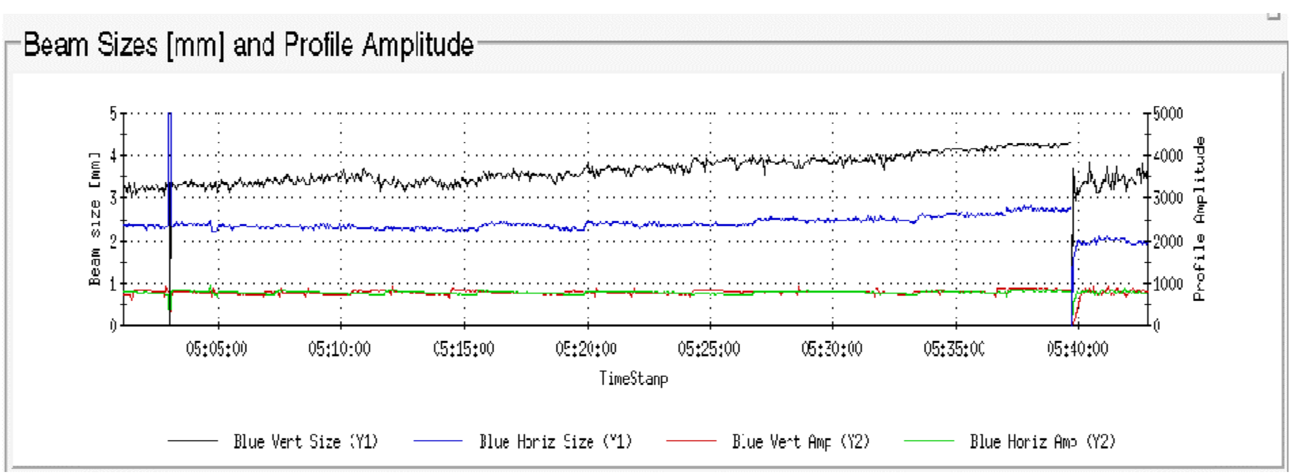

Figure 6: Vertical (top trace) and horizontal (middle trace) beam widths of a single bunch plotted at 4-second intervals for 40 minutes. At 05:40 the bunch was dumped and a new one injected.